MULTIMEDIA UNIVERSITY®

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EEL1176 FIELD THEORY

(All Sections / Groups)

19 OCTOBER 2019
02:30 P.M – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages including this cover page with 4 questions only. Three appendices are provided at the end of the question paper.

2. Attempt all four questions. All questions carry equal marks and the distribution of marks for each question is given.

3. Please print all your answers in the answer booklet provided.

Question 2

(a) State Coulomb's law.

[2 marks]

(b) Find the **electric field intensity** at $P(-0.2, 0, -2.3)$ due to a point charge of +6 nC at $Q(0.2, 0.1, -2.5)$. Assume that the medium is air and all dimensions are in meters.

[3 marks]

(c) Write down an expression for the **force** acting on a point charge of q Coulombs sitting in an electric field with intensity $\underline{\mathrm{E}}$.

[2 marks]

(d) An infinitely long cylinder has a radius of 3 m. It carries a charge density $\rho_v = r\rho_o$ $(\mathrm{C/m^3})$, where r is the radial distance measured from the axis of the cylinder, and ρ_o is a constant.

(i) What is the **electric charge per unit length** carried by the cylinder?

[4 marks]

(ii) Use Gauss's law to determine the **electric field intensity** at a point **inside** the cylinder, which is situated at a distance r from the axis.

[5 marks]

(iii) What is the **electric field intensity** at a point situated at a distance r from the axis **outside** the cylinder?

[5 marks]

(e) A cylindrical bar of silicon has a radius of 1.45 mm and a length of 5 cm. The electron and hole mobility are $\mu_e = 0.13\ \mathrm{m^2/Vs}$ and $\mu_h = 0.05\ \mathrm{m^2/Vs}$, respectively. The electron and hole density are $N_e = 1.6 \times 10^{16}\ \mathrm{m^{-3}}$ and $N_h = 1.6 \times 10^{16}\ \mathrm{m^{-3}}$, respectively.

(i) Determine the **conductivity** σ of the silicon bar.

[2 marks]

(ii) If a voltage of 5 V is applied between the two ends of the silicon bar, determine the **current** I flowing in the bar.

[2 marks]

Continued ...

Question 4

(a) Briefly explain the following terms in the context of magnetic material.

(i) Saturation
(ii) Residual flux density
(iii) Coercive field intensity

[3 marks]

(b) Sketch a **hysteresis loop** in the B-H plane for ferromagnetic material. **Mark** the points corresponding to saturation, residual flux density, and coercive field intensity.

[5 marks]

(c) Consider the magnetic circuit in Fig. Q4. The magnetic core (grey) has a relative permeability of about 1000. The left and right limbs have a cross-sectional area of 9 cm^2. The center limb has a cross-sectional area of 4 cm^2 and a 2 mm air gap. A 200-turn coil is wound around the left limb.

(i) Draw a **circuit model** of the magnetic circuit.

[5 marks]

(ii) Compute the required **current** I if a magnetic flux density of 1 Tesla is desired at the air gap.

[12 marks]

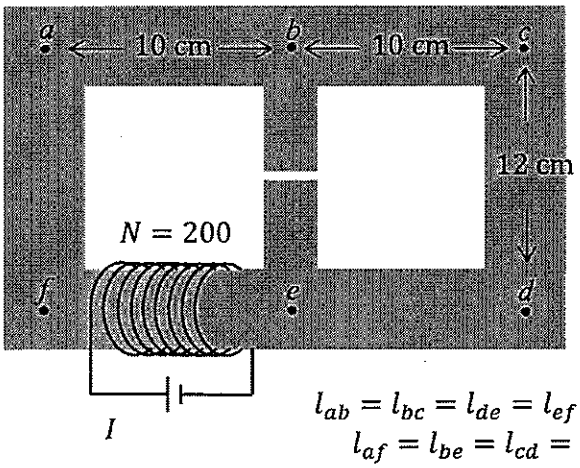

Fig. Q4

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Appendix B: Gradient, Divergence, Curl, and Laplacian Operators

Cartesian coordinate (x, y, z)

$$\nabla V = \hat{x}\frac{\partial V}{\partial x} + \hat{y}\frac{\partial V}{\partial y} + \hat{z}\frac{\partial V}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \vec{A} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} = \hat{x}\left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}\right) + \hat{y}\left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}\right) + \hat{z}\left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right)$$

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}$$

Cylindrical coordinate (r, ϕ, z)

$$\nabla V = \hat{r}\frac{\partial V}{\partial r} + \hat{\phi}\frac{1}{r}\frac{\partial V}{\partial \phi} + \hat{z}\frac{\partial V}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{1}{r}\frac{\partial}{\partial r}(rA_r) + \frac{1}{r}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \vec{A} = \frac{1}{r}\begin{vmatrix} \hat{r} & \hat{\phi}\, r & \hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_r & rA_\phi & A_z \end{vmatrix} = \hat{r}\left(\frac{1}{r}\frac{\partial A_z}{\partial \phi} - \frac{\partial A_\phi}{\partial z}\right) + \hat{\phi}\left(\frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r}\right) + \hat{z}\frac{1}{r}\left[\frac{\partial}{\partial r}(rA_\phi) - \frac{\partial A_r}{\partial \phi}\right]$$

$$\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 V}{\partial \phi^2} + \frac{\partial^2 V}{\partial z^2}$$

Spherical coordinate (R, θ, ϕ)

$$\nabla V = \hat{R}\frac{\partial V}{\partial R} + \hat{\theta}\frac{1}{R}\frac{\partial V}{\partial \theta} + \hat{\phi}\frac{1}{R\sin\theta}\frac{\partial V}{\partial \phi}$$

$$\nabla \cdot \vec{A} = \frac{1}{R^2}\frac{\partial}{\partial R}(R^2 A_R) + \frac{1}{R\sin\theta}\frac{\partial}{\partial \theta}(A_\theta \sin\theta) + \frac{1}{R\sin\theta}\frac{\partial A_\phi}{\partial \phi}$$

$$\nabla \times \vec{A} = \frac{1}{R^2\sin\theta}\begin{vmatrix} \hat{R} & \hat{\theta}\, R & \hat{\phi}\, R\sin\theta \\ \frac{\partial}{\partial R} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_R & RA_\theta & (R\sin\theta)A_\phi \end{vmatrix}$$

$$= \hat{R}\frac{1}{R\sin\theta}\left[\frac{\partial}{\partial \theta}\left(A_\phi \sin\theta\right) - \frac{\partial A_\theta}{\partial \phi}\right] + \hat{\theta}\frac{1}{R}\left[\frac{1}{\sin\theta}\frac{\partial A_R}{\partial \phi} - \frac{\partial}{\partial R}\left(RA_\phi\right)\right] + \hat{\phi}\frac{1}{R}\left[\frac{\partial}{\partial R}\left(RA_\theta\right) - \frac{\partial A_R}{\partial \theta}\right]$$

$$\nabla^2 V = \frac{1}{R^2}\frac{\partial}{\partial R}\left(R^2\frac{\partial V}{\partial R}\right) + \frac{1}{R^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial V}{\partial \theta}\right) + \frac{1}{R^2\sin^2\theta}\frac{\partial^2 V}{\partial \phi^2}$$

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